C3 New Data / TRMM

Assimilation of TRMM and SSM/I-Derived Rainfall and Total Precipitable Water Estimates

The Data Assimilation Office (DAO) has been exploring the use of tropical rainfall and total precipitable water (TPW) observations from the TRMM (Tropical Rainfall and Measurement Mission) Microwave Imager (TMI) and the Special Sensor Microwave/ Imager (SSM/I) instruments to improve global analyses and short-range forecasts. The algorithm is a "1+1"D procedure based on a 6-hr time integration of a column version of the GEOS DAS to assimilate 6-hr averaged rainfall and TPW within the Incremental Analysis Update (IAU) framework (Hou et al., 2000a, 2000b). The scheme minimizes the least-square differences between the observed TPW and rain rates and those produced by the column model over the 6-hr analysis window. This 1+1D scheme, in its generalization to four dimensions, is related to the standard 4D variational assimilation but uses analysis increments instead of the initial condition as the control variable.

Results show that assimilating these data types improves the precipitation and moisture fields and key climate parameters such as the outgoing longwave radiation (OLR) and outgoing shortwave radiation (OSR) as verified against independent measurements by the Clouds and the Earth's Radiant Energy System (CERES) instruments aboard the TRMM satellite. Figure 1 summarizes the impact of rainfall and TPW assimilation on the monthly-mean precipitation, TPW, OLR, and OSR in the tropics for January 1998. Left panels show time-mean spatial errors in the these fields in the GEOS control assimilation. Right panels show the corresponding errors in an assimilation that incorporates the rain rates and TPW estimates derived from the TMI and two SSM/I instruments aboard the Defense Meteorological Satellite Program F13 and F14 satellites. The monthly-mean spatial biases and error standard deviations are significantly reduced in most fields. Two apparent exceptions are the biases in the tropical-mean precipitation and OLR. The slightly larger precipitation bias reflects that the rainfall assimilation algorithm is more effective in reducing than enhancing precipitation. The apparent increase in the OLR bias is due to the virtual elimination of the negative OLR bias associated with precipitation, leaving a tropical-mean bias dominated by the positive (but reduced) bias in the rain-free regions. In the GEOS analysis, much of the errors in radiative fluxes are dominated by errors in clouds. Precipitation assimilation improves the spatial distribution of clouds, as shown in Fig. 2 for the IR cloud radiative forcing for January and June 1998. Rainfall and TPW assimilation improves not only the time-averaged analysis for climate studies but also the instantaneous fields to provide better initial conditions for short-range forecasts in the tropics, as illustrated in Fig. 3.

This work demonstrates the potential of using space-based rainfall and TPW observations for improving numerical weather prediction and the quality of assimilated global data sets for climate research. Current DAO plans call for using an upgraded GEOS-Terra system with rainfall assimilation capabilities to produce a multi-year GEOS-3 reanalysis covering the TRMM period for studying the variability of the hydrological processes and the energy cycle in the tropics.

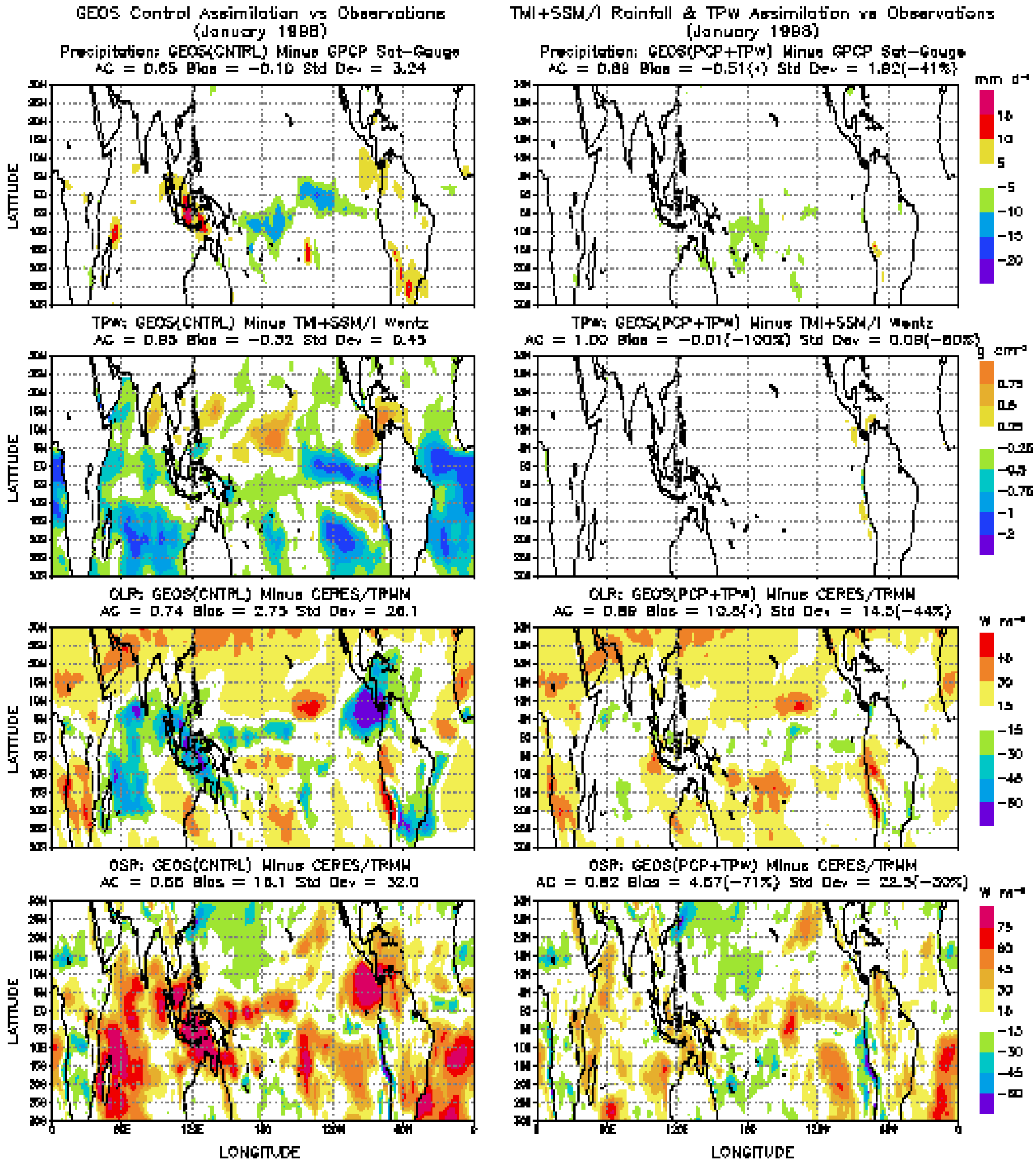

Figure 1. NASA GEOS assimilation results with and without TMI and SSM/I observations for January 1998. Left panels show errors in the monthly-mean tropical precipitation, total precipitable water, outgoing longwave radiation, and outgoing shortwave radiation in the GEOS control assimilation. Right panels show the impact of assimilating TMI and SSM/I rainfall and TPW observations on these fields. Percentage changes relative to errors in the GEOS control are given in parentheses. See text for discussions of bias values accompanied by an asterisk.

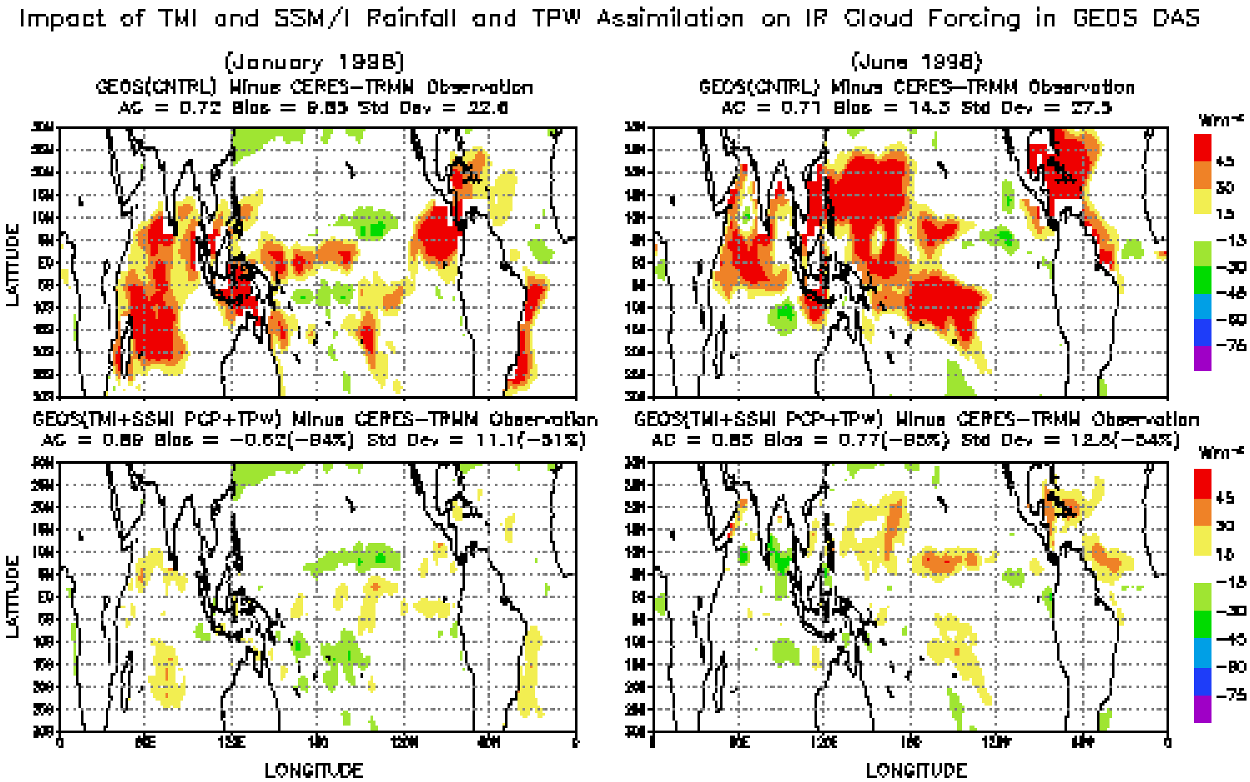

Figure 2. Improvements in the longwave "cloud radiative forcing" in the GEOS DAS as verified against CERES/TRMM observations. Right panels are for January 1998. Left panels are for June 1998. In both cases, assimilation of TMI and SSM/I rain rates and TPW data yields significant reductions in the bias and error std dev in the tropics. Percentage changes relative to errors in the GEOS control are given in parentheses.

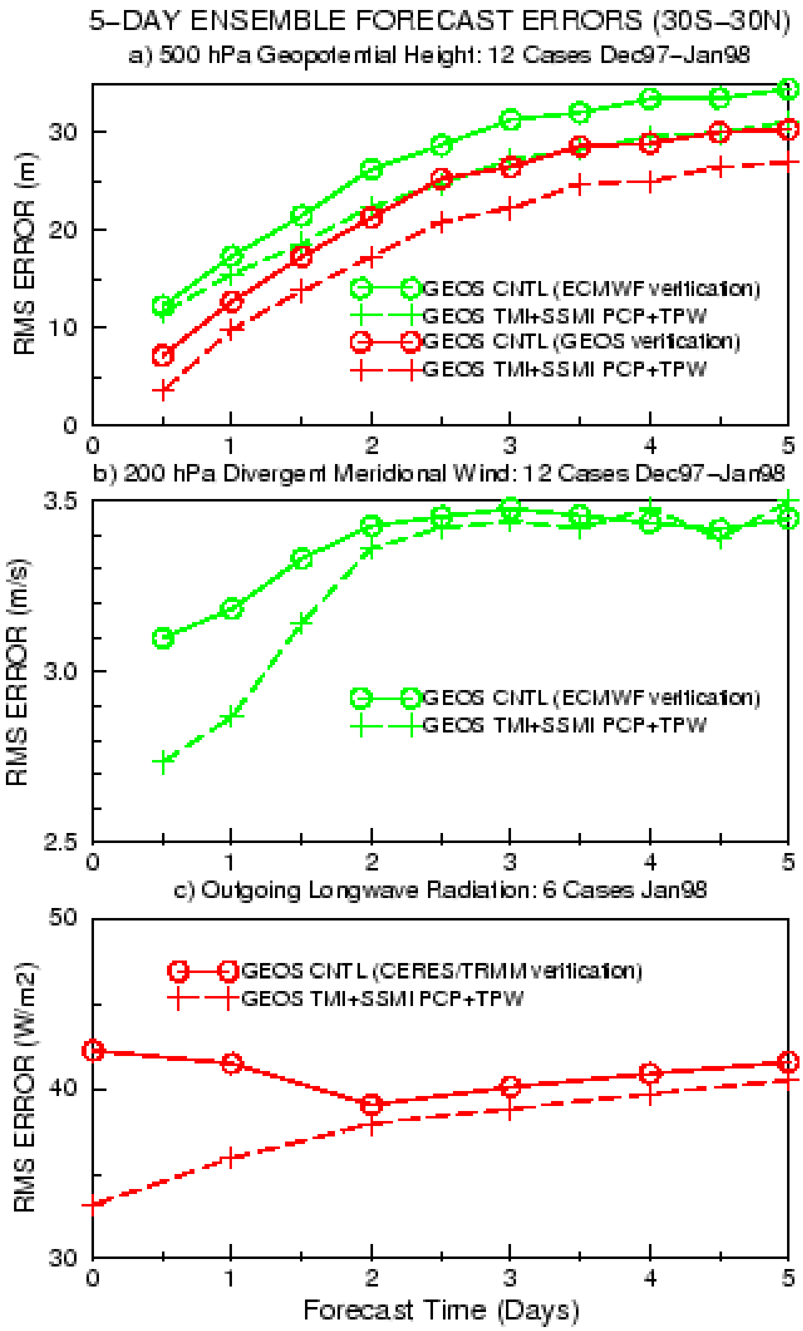

Figure 3. (a) 5-day ensemble forecast rms errors in tropical geopotential height at 500 hPa. Results in green are verified against the ECMWF analysis and results in red are verified against the average of the GEOS control analysis and the TMI and SSM/I rainfall and TPW assimilation. (b) Same as (a) except for the 200 hPA divergent meridional wind verified against the ECMWF analysis. (c) Same as (a) except for the OLR verified against CERES/TRMM observations.

References:

Hou, A.Y., D. Ledvina, A. da Silva, S. Zhang, J. Joiner, R. Atlas, G. Huffman, and C. Kummerow, 2000a: Assimilation of SSM/I-derived surface rainfall and total precipitable water for improving the GEOS analysis for climate studies. Mon Wea. Rev., in press.

Hou, A.Y., S. Zhang, A. da Silva, W. Olson, 2000b: Improving assimilated global data sets using TMI rainfall and columnar moisture observations. J. Climate, submitted.